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Water resource planning and optimizing it using VENSIM model

Case study of Sefidrud watershed

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Abstract

Regarding development in human population as well as the advances of industries and agriculture in the modern world increasingly need for water supply is unavoidable. Furthermore, restrictions in water resources and sustainable water management have made it almost impossible for us to fulfill all the needs for water demand. Thus to provide and highly ensure water supply in terms of priorities such as domestic, agricultural rights, environment, industry and agricultural development, we need a precise and careful planning. In order to optimize the planning, in this study we tried to model the Finesk proposed dam and its watershed by using VENSIM casual model. VENSIM is visual model that can depict, simulate, analyze and optimize a system's dynamic models. In this regard first, stream flow regime and existed water resources in upstream and downstream was determined. Then demands and consumptions were evaluated and finally according to physical dimension of Finesk propose dam, the casual model in VENSIM was created. With considering Ten different plans, the result showed that the optimum condition to satisfy demands, in term of priorities in downstream can be provided by allocating ۸,۶۷ MCM for domestic purposes, ۳,۴۴ MCM for environment aims and ۰,۸۱۲ MCM for agricultural rights.

Keywords: VENSIM, casual model, dam allocation, Finesk dam, water resource management

۱- Introduction

Rapid urbanization and population growth and consequently growth in water usage have worsened problems especially water shortage and insufficient water supply. In addition, a reduction in water availability, conflicting water uses and other water-related environmental problems are rapidly increasing in many parts of the world including Iran. Thus the necessity of water resource management seems unavoidable. In past the human have tried to control the surface water by dams to provide their needs. By exploiting the existing water in better way, we not only can provide our needs, but also the near future. True perception and anticipation from present condition considering the climate in different seasons can lead us to have right plans for utilization.

Different aims in reservoir system analysis resulted to different models. Main goals by designing these models are regulating and evaluating different plans due satisfy water needs. Besides they can be used for reconsidering the reservoir exploitation policies. The most common modeling is simulation. The simulation uses for evaluating the operation and exploitation of existing water resources.

Yeh et al (۱۹۸۵) analyzed different methods of simulation of reservoir management. He found that enough researches and studies have not done in reservoir system analysis to be used in practice. He also noticed that this shortage could be due to lack of operator's experiences and too simplify with computer models. Royston et al (۱۹۹۹) used dynamic systems to satisfy water demand in Lewis Smith multipurpose reservoir on Black Warrior River. He found out the dynamic system model can effectively estimate the actual condition of reservoir. Simonic and Ahmad (۲۰۰۰) simulated exploitation of Shellmouth reservoir on Assiniboine River by using same method. Afshar et al (۲۰۰۴) studied the simulation and optimization usage of Karoon-Dez reservoir. He used dynamic system and simulated with Hec-۵ due to optimize it.

In this study we tried to optimize Finesk reservoir usage by simulating Sefirud watershed. For this purpose we should consider both existing water resources and demands at the same time. It should be noticed that handling and controlling the existing water resources should be without damaging environment, worsen water quality condition and finally with considering international methods to avoid spoiling water resources. In the other hand for estimating demands of water we should consider different fields of usage. Different fields in water usage are agriculture, domestic, industry and environment. Most of used water resources in different fields are not qualified to recycle. Thus it is necessary to increase the efficiency of water usage in these fields and develop latest methods due to estimate the amount of water demand in each field.

As a result, by simulating Sefidrud watershed and using cause and effect model of Vensim for Finek proposed dam, several plans has been tried and optimum allocation was determined.

۲- Materials and Methods

۲-۱- Sefidrud watershed

Sefidrud watershed is considered semidry cold region regarding to its climate. In Sefidrud watershed, the average annual rainfall has been estimated about ۳۷۶ mm, the average annual temperature is ۹ centigrade, the average potential evaporation is ۷۵۳ mm and the number of freezing days has been estimated ۱۳۸ days. Total annual long term surface water resources of area have been estimated about ۲۴,۱ MCM in Finesk proposed dam that includes about ۱۹,۴٪ of the precipitation volume of the area. The drainage of groundwater resources in the upstream basin of the dam is ۰,۱۶ MCM through wells and aqueducts. From total resources of surface water and ground water, ۵,۷MCM water has been allocated mainly to agricultural consumptions. Finesk dam is one of under study plans for domestic water supply for Semnan and Mahdishahr cities and also agriculture and environment needs in downstream. These cities are located in south skirts of Alborz Mountain and the central watershed basin and considered as one of water transfer plans between basins in this region.

۲-۲-VENSIM model

Vensim is a visual modeling tool that allows you to conceptualize, document, simulate, analyze, and optimize models of dynamic systems. Vensim provides a simple and flexible way of building simulation models from causal loop or stock and flow diagrams. By connecting words with arrows, relationships among system variables are entered and recorded as causal connections. This information is used by the Equation Editor to help you form a complete simulation model. You can analyze your model throughout the building process, looking at the causes and uses of a variable, and also at the loops involving the variable. When you have built a model that can be simulated, Vensim lets you thoroughly explore the behavior of the model**.**

۲-۳- Sefidrud watershed VENSIM model

The model of Sefidrud watershed is offered by considering the effects of constructing Finesk dam and transferring surplus water at non-cultivating seasons for agriculture water rights, the needs of downstream environment of dam and also the allocation from the place of this plan were considered in this model. Initially, the model of the dam is made as figure (۲). The equation of general dam water budget is as follow:

$$\text{Inflow} - \text{outflow} - \text{spill} - \text{evaporation} = \Delta V \qquad (۱)$$

Where, ΔV is the variation rate of reservoir volume.

The monthly Inflow rate as a boundary condition is estimated by considering ۳۰ years in watershed basin after resolving the effect of the development by using water in the upstream. The dam model is formed by assuming the initial volume of the reservoir to the half of its maximum capacity. The evaporation rate from the lake of the dam is calculated by using the level-volume-height diagram and finally total volume of the dam is determined in each month. On the other hand, required water and the priorities of its supply with the segregation of needful centers such as domestic, environment, industry and agriculture centers are included in the model respectively. Considering the volume of reservoir in each month, the model supplies the needs by considering priorities in every time stage. With subtracting the Total Demand from the Total Supply we can obtain the shortage, and It should be noticed that the rate of allocated water to domestic purpose is exited from cycle right in dam's construction. But environmental discharge with overflow of the reservoir and the agriculture water rights of downstream are considered as the dam output and the dam trace. In fact, the exact consumption rate of the reservoir is the allocated water to domestic section and also the evaporation from the lake.

۳- Results and Discussion

Ten different plans have been studied for obtaining an optimum option for supplying the needs. Four options satisfied the acceptable ranges and finally the second option has been chosen as optimum. In table (۱), the rate of volume and time supply has been shown for every option. The acceptable ranges of needs are ۹۵-۱۰۰% for domestic, ۹۰-۱۰۰% for industry and ۸۰-۱۰۰% for agriculture. This range is determined by Iran Water Resource Management cooperation. It should be noticed that the supply of industrial needs has been omitted from a cycle by regarding the priority of domestic needs. The rate of volume and time supply for domestic purpose is assumed ۳۰۰ and ۲۵۰ L/S in each month for the first and second six months respectively. It is observed in table (۱), regarding the priority of domestic water supply with higher volumes, it is possible to supply more domestic water in first option. On the other word there is still an opportunity to increase the domestic volume, therefore for the optimum exploitation the allocated volume have been increased in next options. In the other hand the time confidence of supplying domestic water in third and forth options is lower than second

option. Finally, by considering the amount of domestic supply and time confidence in second option with available standards, it is introduced as the optimum managerial option to satisfy the needs. In this option, the shortage of environmental water supply is compensable by overlapping agriculture needs at cultivation seasons.

All defined variable of the model such as state and decision variable were calculated for all time stages. the monthly volume and time confidence supply of the needs are also calculable. The resulted calculation related to second option is presented in figure (۳) and (۴).

As it is shown in figure (۳), changing in the reservoir volume directly depend on inflow rate. According to reservoir maximum capacity the rest of inflow will be spill. But the output, due to satisfying the needful of different demand centers with ۹۵٪ time confidence will be changed. It is shown in Figure (۴), how the supply and demand are coincided in plan two. In fact when supply and demand are exactly adapt, it means all the demand will be satisfied. There are also some shortages in some months that the plan cannot supply the demand. As it is shown in figure (۴), there are about ۰.۲ MCM each month shortages in months ۳۷ to ۴۰ and more than ۰,۲ MCM each month in months ۳۱۰ to ۳۲۰.

۴- Conclusion

In this study, Sefidrud watershed was simulated by using VENSIM, the cause and effect model. This model has been studied to evaluate the allocation of downstream needs. The optimum allocation rate from Finesk proposed dam has been determined by considering the priorities of domestic, environment purposes, agriculture water rights and industry. But the industry needs according to the priority of domestic and environment and also little demand of industry neglected. Regarding tested several different scenarios plan number two was selected as the optimum option for allocation. Also studies have showed that according to execution of the plan, ۸,۶۸ MCM each year with ۹۵٪ time confidence can be supplied to Semnan and Mahdishahr domestic purpose. Consequently ۳,۴۴ MCM And ۰,۸۱۴ MCM each year was considered with ۸۶٪ and ۸۸٪ time confidence for environment purposes and agriculture rights respectively. The shortage of environmental water supply is compensable by overlapping agriculture needs at cultivation seasons. As a result, by considering this

model, we can optimize the exploitation of Finesk dam from single purpose to multipurpose. Obviously the model needs verification. It can be done after the dams building will be constructed. It can also reconsider after verification for new policies and demands.

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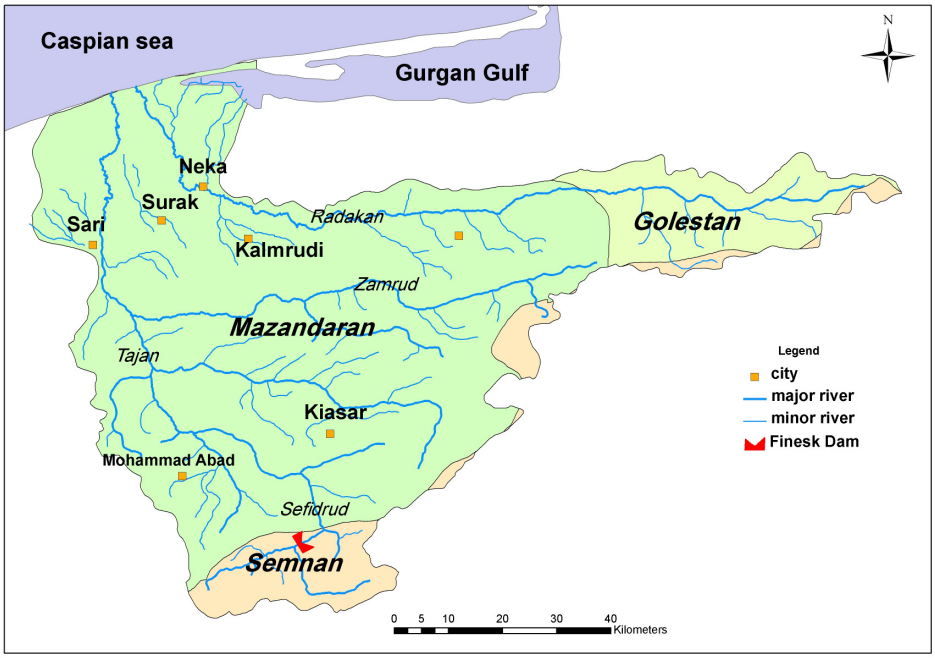


Figure (۱): Sefidrud watershed and location of Finesk dam

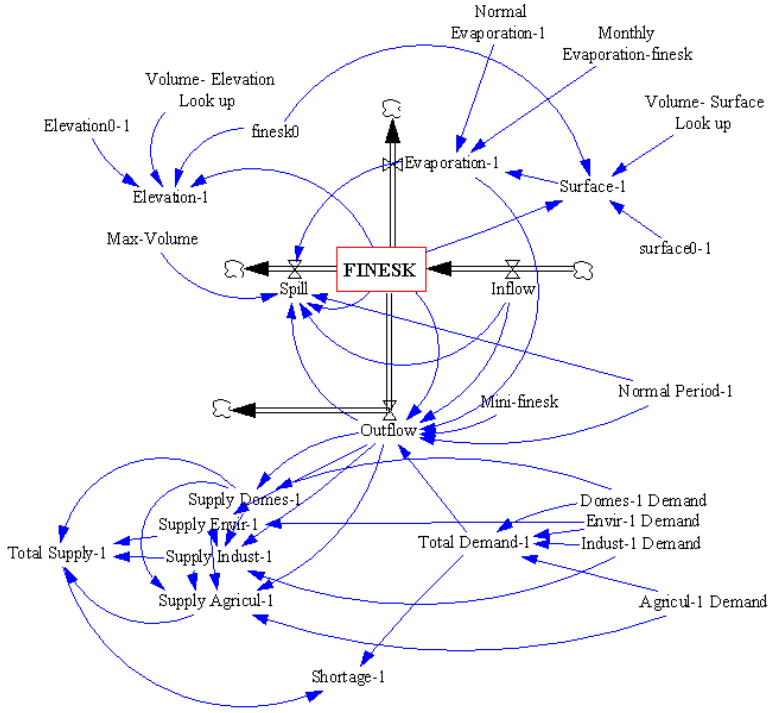


Figure (۲): Water resources and consumptions model of Finesk dam

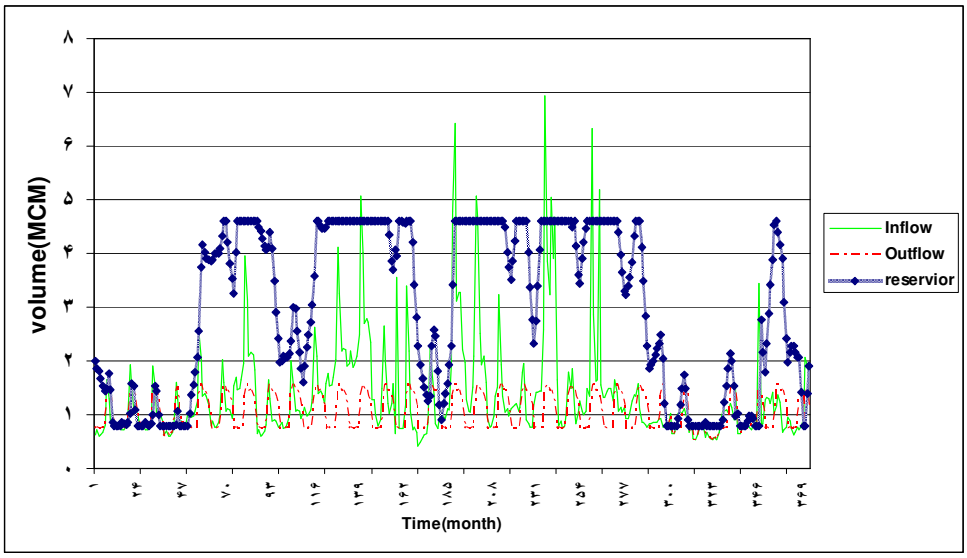
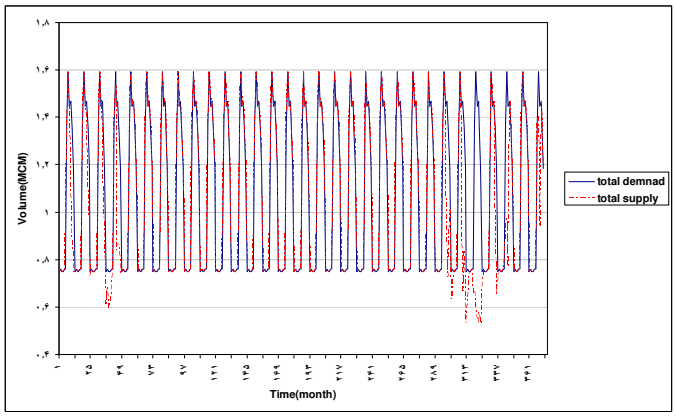
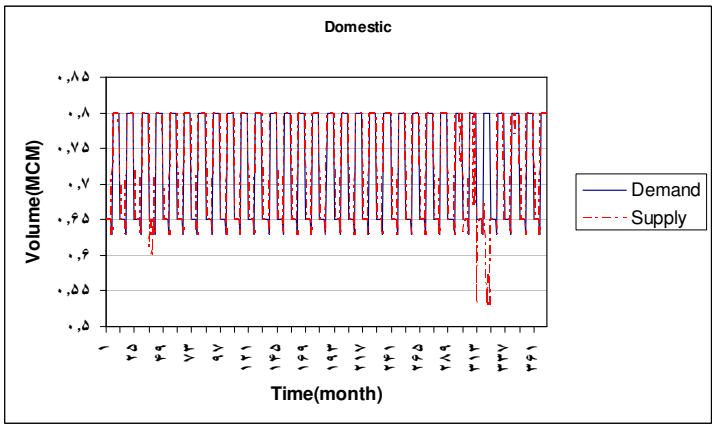


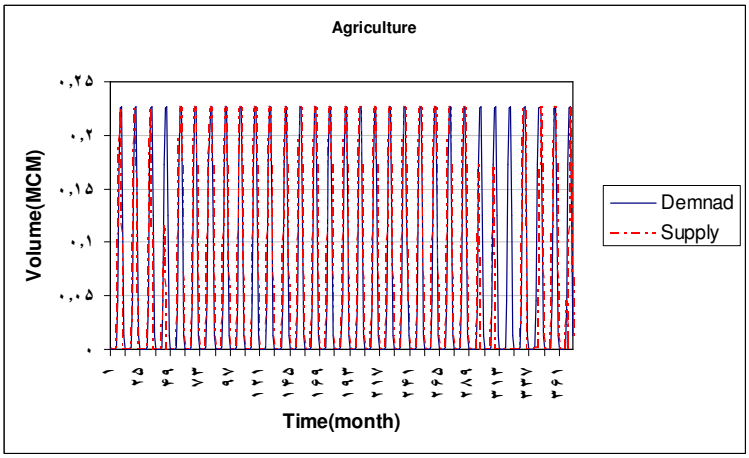
Figure (۳): estimated inflow, outflow and reservoir volume change



a) Total supply and demand



b) Domestic supply and demand



c) Agriculture supply and demand

Figure (۴): supply and demand due to plan number ۲

Table (١): different acceptable option for allocate

	domestic			environment			agriculture		
	Volume (MCM)	Volume (%)	Time confidence	Volume (MCM)	Volume (%)	Time confidence	Volume (MCM)	Volume (%)	Time confidence
option ١	٧,٨٩	٩٩,٦٠٪	٩٦,٢٠٪	٣,٤٤	٩٢,٦٠٪	٩٠٪	٠,٨١٤	٩٠٪	٩١,٤٠٪
option ٢	٨,٦٨	٩٩,١٠٪	٩٥٪	٣,٤٤	٩٠٪	٨٦٪	٠,٨١٤	٨٢٪	٨٨٪
option ٣	٩,٤٣	٩٨٪	٩٠٪	٢,٦٤	٩٠٪	٨٥٪	٠,٨١٤	٨٨٪	٩٠٪
option ٤	٩,٩٩	٩٦٪	٨٧٪	٢,٦٤	٨٨٪	٨٢٪	٠,٨١٤	٨٧%	٨٧٪